TA
420
.L3

TA 420
.L3
Copy 1

TRANSVERSE STRENGTH OF LARGE SPRUCE BEAMS.

FROM TESTS MADE AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY,

AN ADDRESS

DELIVERED BEFORE THE SOCIETY OF ARTS OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY,

119092

BY PROF. GAETANO LANZA.

Copyrighted by Professor Gaetano Lanza.

BOSTON:
Press of the Boston Journal of Commerce Publishing Company.
1882.

TRANSVERSE STRENGTH OF LARGE SPRUCE BEAMS.

FROM TESTS MADE AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

AN ADDRESS

DELIVERED BEFORE THE SOCIETY OF ARTS OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

30/9214

BY PROF. GAETANO LANZA.

From the Boston Journal of Commerce, June 24, 1882.

For a long time, I have been very anxious to supplement my instruction in the strength of materials with actual tests, so that the students, by performing the experiments themselves, might better understand the behavior of the materials when under stress and strain. In order to accomplish this result, one or more testing machines were needed, and of sufficient power to make tests on such a scale as to furnish reliable information.

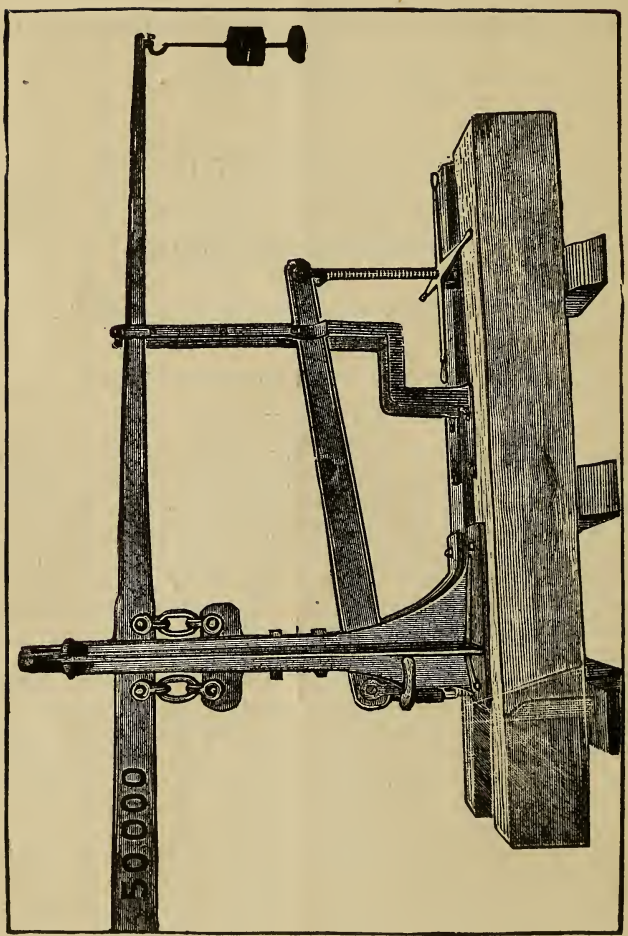
In the summer of 1881 an opportunity presented itself to purchase a testing machine of 50,000 pounds capacity for a price which encouraged me to hope for success, and, having found some kind friends who were willing to furnish the money, I proceeded to purchase the machine for the institute. It was adapted to exert a tensile stress on specimens of about 12 inches in length, and also for the compression of small cubes. It was an old style Fairbanks machine, and was sold to me by Messrs. Riehle Bros., of Philadelphia, who had just put in its place, in the shops of the Pennsylvania railroad, one of their own make of 100,000 pounds capacity.

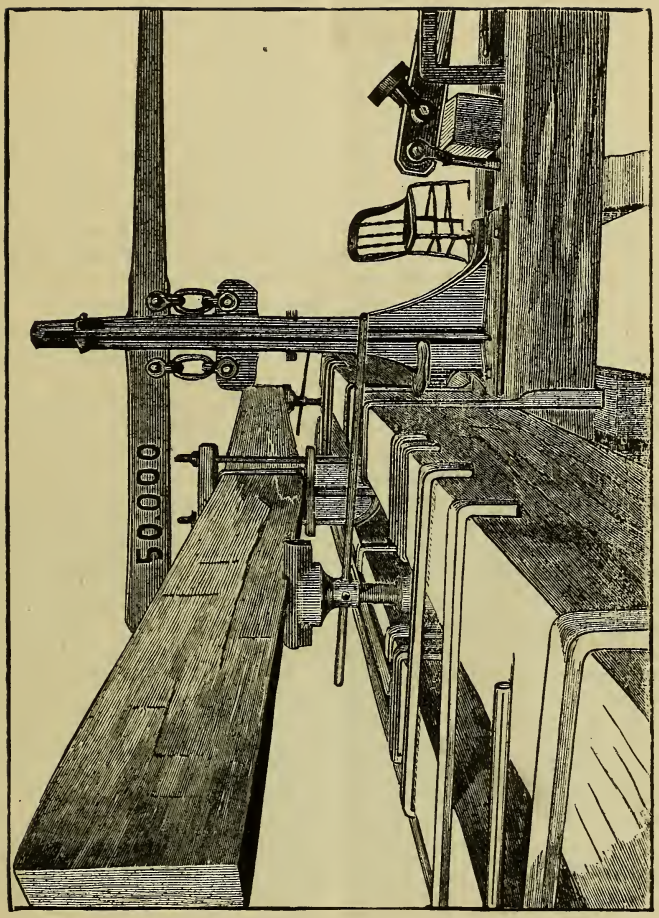
The machine when received consisted, as is shown in the first cut, of a compound scale beam hung from a cast iron frame, by means of which the tension is measured, and below this a lever for exerting the pull, operated at the farther end by a screw, as shown in the cut. This screw, which was only 12 inches long, I replaced by one which was 24 inches long. With the machine, as thus equipped, we have been able to perform quite a number of experiments on tension. Besides this, by altering the position of the lower lever and of the screw, we have been able to test specimens about three feet long. I have also devised a pair of clamps, which, with the aid of a micrometer screw, enables us to measure the stretch of the specimen under any given load to within one ten-thousandth of an inch.

The following are the tensile experiments that have been made by the fourth year students of applied mechanics:

1. Tensile strength and contraction of area of boiler plate, by Messrs. Snow and Manning.
2. Strength of upset and of plain iron bolts, by Messrs. Johnson and Morrison.
3. Tensile strength and contraction of area of steel boiler plate, by Messrs. Ross and Cheney.
4. Tensile strength of wire rope, by Messrs. French and White.

TA420
.L3




50,000

5. Strength of riveted joints, by Messrs. Carson and Ripley.

6. Modulus of elasticity of tire steel, by Messrs. Faunce and Munroe.

These students have all given me written reports of their work, in the course of which many points of very considerable interest have been developed. Besides this, opportunity has been furnished the students to familiarize themselves somewhat with the behavior of the metals under stress and strain by actual experiment. Nevertheless, it is not my object, this evening, to take up your time with a detailed account of these experiments on tension, and I shall therefore pass at once to a consideration of the transformation that has been made in the machine to adapt it to the testing of large beams transversely loaded, and of the results obtained by using the machine as thus equipped, inasmuch as it has already revealed, in this department, some facts which, as I believe, are of great importance to builders, and which tend to overthrow certain misconceptions in regard to the transverse strength of spruce timber. Indeed, in my anxiety to have a testing machine in my department, the desire to test, by its means, full size beams, has perhaps been uppermost in my thoughts, for the data most commonly given us for the computation of wooden beams in our text books and engineers' hand books have been derived from the results of experiments on beams of a very much smaller size than those used in practice, and hence upon pieces not containing the knots and defects that are almost invariably found in larger pieces.

The transformation referred to is shown in the second cut. The lower lever shown in the first cut was removed, and the holder of the compound lever, was connected by means of a steel rod and turn-buckle, with one end of a lever of equal arms placed below, this lever having a 12-inch leverage and being connected at its other end by means of a chain, with the yoke shown in the second cut. Two hard pine beams, each 20 inches deep, 10 inches wide and 26 feet long, were placed across the timbers of the machine in such a way that the chain already referred to should be midway between them. Two common jackscrews, each in a pair of wrought iron stirrups, are placed at a distance apart, depending upon the span of the beam to be tested, the latter being placed, as shown in the second cut, upon the jackscrews and under the yoke. The jackscrews are then screwed up, and the beam to be tested is thus raised at its two ends, and hence loaded at the point where the yoke is attached. In the cut, the beam represented is a 4x12 inch spruce beam, the jackscrews being placed respectively at distances of 4.5 and 11.5 feet from the point where the yoke is attached. The fracture is shown in the figure.

As to the capabilities of the machine, any beam can be broken by its means, which is not more than 25 feet long (between supports) and which does not require more than a load of 50,000 pounds to break it. As to its accuracy, I will say that I have the written certificate of Messrs. Fairbanks, Brown & Co. for the correctness of both the compound scale beam and also the equal armed lever, the first of which they put in order, and the second they examined and found correct, it having been made at the Norway Iron Works. Besides this, however, the machine as a whole has been tested and proved correct by means of a steelyard of 1450 pounds capacity (for whose correctness I have also a written certificate from Messrs. Fairbanks, Brown & Co.), by suspending the steelyard from a rod supported on the jackscrews and attaching to it the chain of the equal armed lever.

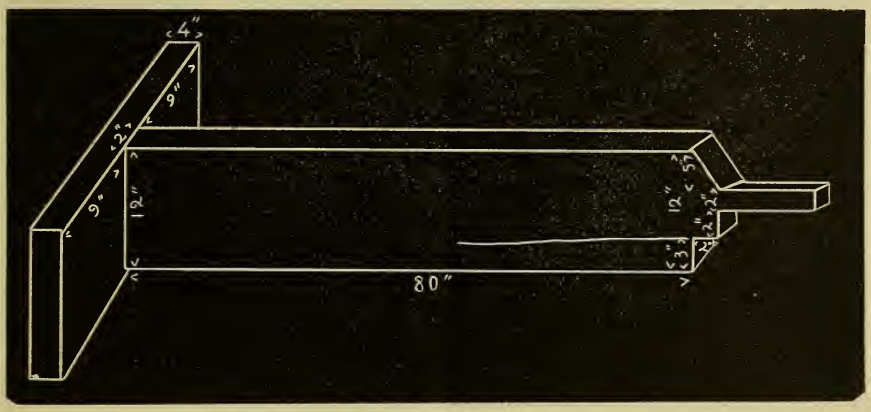
As to the tests that have been made thus far, they have been but few, for the reason that the machine has only been adapted to the testing of transverse stress since March 1, 1882. Indeed, in the early part of the session, while the students were making their tensile tests, I, and my assistant, Mr. Wilkes, were making the calculations and drawings necessary for the transformation to a transverse machine; and subsequently the different parts were made for me of steel, at cost, through the kindness of Messrs. Naylor & Co. All this necessarily required time, and it was only in February that the equal armed lever was completed, and then the remainder of the month was required for its erection, and the preparation of the accessory apparatus.

The following table gives the list of the tests that have been made by the students, and immediately after I will give a detailed account of them:

TABLE OF TESTS

MADE BY STUDENTS OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

Names of students making the tests.	Number of test.	Width and depth in inches.	Distance between supports.	Manner of fixing the ends and loading.	Breaking weight in pounds.	Modulus of rupture in lbs. per square inch.	Trautwine's form. Central breaking weight of beam 1″ square and 1′ long, supported at ends.	Barlow's form. End breaking weight of beam 1″ square and 1′ long, fixed at one end only.
Messrs. Ely, Heins and Snelling.	1	2 x12	6′ 8 ″	Framed at ends.	6,504	.....	.....	.....
	2	4 x12	6′ 8 ″	Header.	10,338	.....	.....	.....
	3	2 x12	15′	Load at middle.	5,894	5,526	307	921
	4	2 x 9	6′ 7.5″	" "	7,322	5,389	299	898
	5	2 x12	15′	" "	5,586	5,237	291	873
	5 (a)	2 x12	7′	" "	8,982	.....	.....	.....
Messrs. Foss and Stebbins.	6	2.75x 9	6′ 8 ″	" "	7,586	4,082	226	680
	7	3 x 9	4′	" "	11,086	3,285	183	548
	8	3 x 9	10′	" "	6,086	4,508	250	751
	9	3 x 9	15′	" "	5,086	5,651	314	942
	10	3 ⅞x12	20′	" "	6,586	4,253	237	709
	11	2.5 x13.5	10′	" "	9,585	3,787	210	631
	12	3.75x12	16′	Load 4.5′ from one support.	7,585	3,271	182	645
	13	3.75x12	16′	Ditto mortised.	9,085	.....	.....	.....
Messrs. Johnson and Morrison	14	7 x 2	7′	Load at middle.	1,944	8,748	486	1,458
	15	1.75x 6.75	7′	" "	4,785	7,562	420	1,260
	16	3 x 9	6′ 8 ″	" "	9,985	4,931	274	822
	17	3 x 9	6′ 8 ″	Load distrib. at 4 points, 16″ apart.	16,744	4,961	276	827
	18	3.9 x12	16′	Load 4.5′ from one support.	12,585	5,218	289	869
					13)60.099			
					4.623		257	770

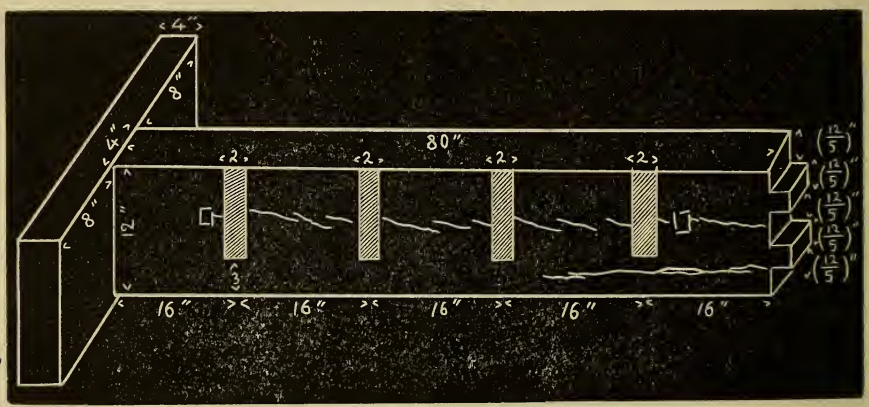


All the beams tested by the students have been of spruce, for the reason that it seemed better to keep to one kind of timber until we should have a sufficient number of results to justify us in drawing some conclusions, and also because spruce is very extensively used in construction. The attempt was made to secure such ordinary stock as is commonly used in building. The lumber for the tests 1, 2, 3, and 4, was secured through the carpenter of the institute, at the place where he usually buys his lumber, and he was requested to obtain the same quality of stock as he ordinarily buys. The greater part of

remaining lumber was obtained from Messrs. Stetson & Moseley, and all that they furnished is stated to be merchantable stock, or such stock as they use to fill their orders. I ought to except, however, Nos. 14 and 15, which had been seasoning on the wharf since 1877, and were quite small. Some of the later sticks were bought from Mr. J. W. Leatherbee.

The first test was made on a 2x12 inch beam, framed at each end into a 4x12 inch beam, with the framing joint shown in the figure. The beam was loaded at the middle, and gave way by splitting at the point shown in the figure.

The second test was made on a header, 4x12 inches and 6 feet 8 inches long, framed into the two trimmers, with a double tenon and a joint bolt, as shown in the sketch; the load was equally divided between the four points directly above the mortises cut for the tail



beams, which mortises were filled up with the tenons themselves. The first breakage, which occurred under a load of about 9000 pounds, consisted of a splitting along the middle of the depth, and the final breakage of a splitting along the lower line shown in the sketch. The remainder of the tests were all made on beams.

No. 3 was a 2x12 inch beam, and while the load reached momentarily 5894 pounds, which I have called the breaking load, the beam had opened a crack at about the middle of its depth, extending for about one-half its length, at a much smaller load, and the load (5894 pounds) having been left on—though falling off rapidly—all night, the next morning the beam bore only 3650 pounds before breaking.

No. 4 calls for no special comment.

No. 5 had the heart of the wood not at middle of the depth, and after it had been broken a portion of it, cut from one side of the middle, was tested again with a span of seven feet. This piece is marked 5 (*a*) in the table. It will be seen that it bore only 8982 pounds before breaking, the reason of this being that long before it broke the cracks at the heart had so opened that a portion of the beam about two inches in depth was not aiding in any way the bearing of the load, as it was simply connected by shreds, and could be easily shaken with the hand.

Nos. 5, 6, 7, 8, 9, 10 and 11 call for no special comment other than their age, which I shall refer to later.

No. 12 contained quite a number of knots and defects, and was in appearance as well as in fact quite a poor stick; it was tested with one concentrated load as described in the table, and gave a modulus of rupture of only 3271 pounds per square inch.

No. 13 was a very good stick, and it was tested with mortises cut for a double tenon just below the place where the load was applied; of course no modulus of rupture can be estimated but if its breaking weight be compared with that of No. 18, which was of about the same quality, some idea can be formed of the loss of strength due to the mortising.

In regard to the age and place of felling of the timber, I have the following information

from Messrs. Stetson & Moseley: Nos. 5, 6, 7, 8, 9, 10, 11, 12, 13, 16, 17, and 18 were cut at Bangor, Me.; Nos. 14 and 15 at Jerusalem township, Franklin Co., Me. Nos. 5, 9, 10, 12, 13, 16, 17, and 18 were cut in the season of 1881; Nos. 6, 7, 8, and 11, season of 1880; Nos. 14 and 15, winter of 1877.

As to the quality of the timber, it was, as I have said, with the exception of Nos. 14 and 15, all common merchantable stock; some of it, that cut in 1880, was rather drier than is ordinarily used; some of the sticks were better than others, as will readily be seen by comparing the moduli. No. 18 was selected by Mr. Wilkes at Mr. Leatherbee's, and was the best stick of that size in the pile at the time; it was considerably better than the average, having no large knots and very slight cracks, and being very straight grained. The average of the thirteen specimens tested gives a modulus of rupture of 4623 pounds per square inch, the lowest being 3271, and the highest of the ordinary stock 5651.

It is therefore unsafe to use figures greater than these, when the stock is such as was tested. For convenience of reference, for those who are accustomed to use the constant in some other form than the modulus of rupture, I have given the constant in the form used by Trautwine in his handbook, and also that in the form used by Barlow, the former being the calculated central breaking weight of a beam one inch square and one foot long, this being one-eighteenth of the modulus of rupture, and the figures in the last column being one-sixth of the modulus of rupture.

In the case of Nos. 14 and 15 we have two pieces of timber of rather small dimensions, which had been seasoning on the wharf for four years, without being exposed to stress or strain. These gave very high moduli compared with the others, the first one being tested flatways, like a plank, and giving 8748, while the last, which was tested edgewise, gave 7562.

Now, while my object is to ascertain the facts in these matters and to teach these facts to my students by giving them the opportunity to ascertain them for themselves; nevertheless, it is a perfectly proper question to ask how these moduli of rupture compare with those commonly given by our text books and engineers' handbooks. To answer this question I will give below the values of the moduli of rupture of spruce given by different authorities, for the sake of comparison, deducing the modulus of rupture from their constant when this is given in some other form:

	Max.	Min.	Mean.
Hatfield gives	12,996	7,506	9,900
Rankine gives	12,300	9,900	11,100
Laslett gives	9.707	7,506	9,045
Trautwine gives			8,100
Rodman gives			6,168

Hatfield's, Laslett's, Trautwine's and Rodman's figures are from their own experiments, and as is evident from the above table, they differ very considerably. Trautwine advises for practical use to deduct one-third, on account of knots and defects, hence after making this allowance he would use 5400. My own figures would give this only for the best of the stock in common use, and in the case of knotty and poor timbers would give much lower values; I obtained as low as 3271 and an average of 4623.

Another question which it is perfectly fair to ask, and perfectly reasonable to expect me to answer is, Why these differences? The main reason seems to me to lie in the fact that the experimenters have generally used very small pieces, one or two inches square and about five feet long; now such pieces are taken free from the knots, and cracks, and defects, and also from the lack of homogeneity, that are always found in larger timber. Besides this, there are the facts that the experimenters generally use straight-grained and well-seasoned timber, and also that timber has a much better chance for seasoning when in such small pieces than when in large ones. The figures obtained by Rodman are very much smaller than the others, and it looks as though they must have been obtained from pieces somewhat larger than those usually experimented upon; they are not at all as small, however, as those which I obtain. On this modulus of rupture (Rodman's) are based the tables given in the handbook of Messrs. Stetson & Moseley.

We need of course to prosecute the subject further and to make an extensive series of experiments determining the strength of timber obtained from various places and of various degrees of seasoning, and also of old timber that has been in use, and to determine as

far as possible the effect of certain defects, such as the cracks that are constantly found at the heart of the timber, and what we have already done shows that these cracks have, at least in certain cases, a very decided effect in weakening the timbers. Also the effect of time on the breaking weight should be examined. Of course we shall hereafter follow up these lines of investigation, not only in the case of spruce, but also in the case of other kinds of timber used in construction, such as yellow pine, etc.; also the deflection and stiffness of timber used in construction. In this regard we have thus far tried three experiments, which gave for the modulus of elasticity of the timber used as follows:

No. 3	1,237,215
No. 4	1,067,893
No. 6	938,453
	3) 3,243,561
Average	1,081,187

I do not pretend to say that this result would be a correct average value for the modulus of elasticity of ordinary spruce timber, as the determination of that would require more than three experiments; but this can be used until we have more light on the subject, and it will be found to be far below the value deduced from tests of small sticks such as are commonly experimented upon.

At the close of the meeting the audience were invited to witness the breaking of a 4x12 inch spruce beam centrally loaded 18 feet between the supports. The beam was the best that could be selected of that size on the previous day from Mr. J. W. Leatherbee's pile of lumber, and was fully up to the average of the ordinary stock. It broke with a load of 8000 pounds. This gives for modulus of rupture 4500 pounds per square inch.

Since the above paper was presented to the society some other developments have occurred, which I will proceed to mention:

1. Desiring to prove by actual comparative test the truth of the ideas I advanced in the paper, I proceeded as follows: About a month before the meeting I had bought at a carpenter's a very good, straight grained spruce plank which had been lying in a warm room for a long time, perhaps a year. I had him cut off for me some little beams about 1.5x1.75 inches, and then tested the remainder of the plank, which was 2x6½ inches, as a beam edgewise, with an eight foot span. It gave a modulus of rupture of 7160, and subsequently testing the small pieces, which had been lying in my study for about a month, we obtained as moduli of rupture respectively 12,323, 13,350, 13,997, thus bearing out very neatly the ideas already advanced.

2. My attention has been called by a friend to an article in Engineering, of April 23 and May 7, 1875, by Mr. C. Graham Smith, giving an account of some results obtained by him, by experimenting on a few large beams. While he gives no results for spruce, his moduli of rupture for other woods are much lower than those obtained by experimenters who have used small pieces.

3. I have just received a letter from Col. T. T. S. Laidley, of the Watertown arsenal, in which he says: "I have just come across some of the old specimens used by Rodman in determining the transverse resistance of woods. The pieces are 5 feet in length, 5¾ inches deep, and 2⅞ inches wide. The distance between supports was about 50 inches." This bears out very neatly my suspicions in regard to Rodman's experiments, as the pieces he used would naturally contain more defects than the very small pieces; nevertheless, my tests on full size pieces give even smaller results in most cases.

LIBRARY OF CONGRESS
0 019 418 217 A

LIBRARY OF CONGRESS
0 019 418 217 A